Winner of the 2013 AAUW
Battle of the Plans: Engineer a Lesson contest

Learn more at www.aauw.org.

Fifth Graders can be Industrial Engineers, too!

A Greeting Card Assembly Line

Heather Krey

Kutztown University

Table of Contents

Author's Note: This lesson is not copyrighted, and I welcome educators, troop leaders, and volunteers of any kind to use it in part or in whole to teach our students about engineering. If you have any questions or would like additional material, I can be contacted by email at heatherkrey@rcn.com. If you do use the lesson, I would love to hear about it!

Fifth Graders can be Industrial Engineers, too!

A Greeting Card Assembly Line

Lesson Overview: In this collaborative math and art lesson, fifth grade art students design their own assembly line and work together to mass produce greeting cards. Ideas central to the profession of industrial engineering including productivity, efficiency, and quality are explored in a fun and age-appropriate way.

Designer: Heather Krey, Kutztown University

Grade Level: This lesson is designed for the fifth grade, but it could be used for students as old as high school seniors with modifications.

Teachers: Ideally, an art and math teacher will work together to teach this lesson. If it is not possible for two teachers to be present, a parent volunteer can assume the open role.

Time Frame: 1.5 – 2 hours

Materials Needed: Whiteboard, white board markers, stopwatches, sample greeting card, 7 posters, 12 small signs with Velcro (or large post it notes) that can be affixed to the posters, 2 bins or boxes labeled "pass" and "fail", and enough card making materials (card stock, scissors, glue, etc.) for each student to make about ten cards

USA- Common Core State Standards (June 2010):

Standard for Mathematical Practice: 1. Make sense of problems and persevere in solving them

Standard for Mathematical Practice: 4. Model with mathematics

Standard for Mathematical Practice: 5. Use appropriate tools strategically

Grade 5 Standards:

Domain: Number and Operations in Base Ten

Cluster: Perform operations with multi-digit whole numbers and with decimals to hundredths.

Standard: 6. Find whole-number quotients of whole numbers

Domain: Measurement and Data

Cluster: Represent and interpret data. 2. Make a line plot to display a data set of measurements in fractions of a unit (1/2, 1/4, 1/8). Use operations on fractions for this grade to solve problems involving information presented in line plots.

Objectives:

Students will be able to:

- Use art materials to create a greeting card based on a predetermined design
- Work together to design an assembly line
- Evaluate and improve the assembly line
- Understand the definitions in the vocabulary list
- Develop an appreciation for the profession of industrial engineering

Essential Question: How can we produce greeting cards as efficiently as possible without sacrificing quality?

Vocabulary:

Industrial Engineer – a type of engineer who is concerned with efficient production

Productivity – A measure of total output

Efficiency – A measure of output per unit of time

Quality – the degree of excellence or acceptability

Quality Control – the process that ensures the quality of a product

Assembly Line – an arrangement of machines, workers, and materials organized in such a way that at each stage an additional part of the manufacturing process is carried out

Task – an individual step in a more complex process

Workstation – a location where specific tasks are designated to be carried out

Line Balancing – the process of assigning tasks to workstations so that the total time to complete the tasks at each workstation is approximately equal

Bottleneck – the workstation that take the longest to complete its tasks

Idle Time – a period of time in which workers are not productive

Warehouse – a place to store materials

Pre-Class Preparation:

Seven large signs should be created that read *Warehouse, Quality Control, Workstation 1, Workstation 2, Workstation 3, Workstation 4,* and *Repair Shop.*

The art teacher should design a greeting card that takes several steps to create, as it will need to be produced in an assembly line. This could be a thank you, happy birthday, or any other type of greeting card. The design should incorporate the school's name and be appropriate for the season.

The teachers should break down the card making process into about 12 steps and prepare small signs for each individual step. These signs should either have Velcro on the back or simply be written on post-it notes so that they can be affixed to the workstation signs by the students.

The room should be set up so that each student will have individual work space, but flexibly enough that the students can work in groups later in the lesson. There should also be areas designated as the warehouse (where the materials will be located) and quality control (where the pass and fail bins will be located).

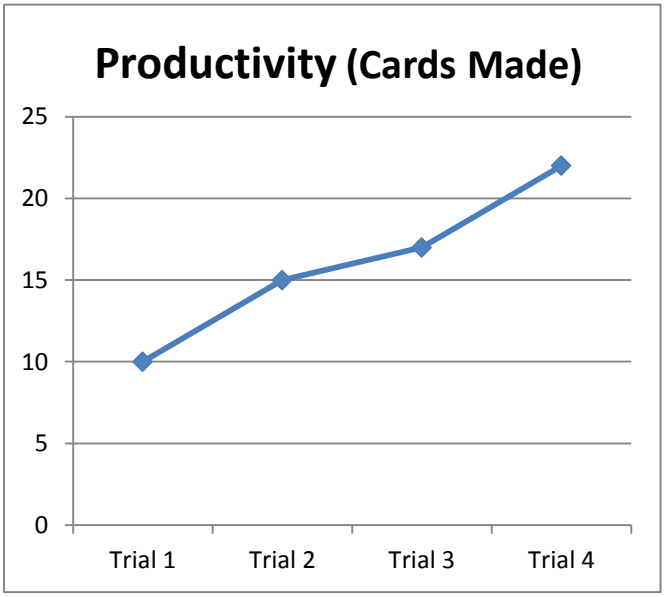
Instructional Procedure:

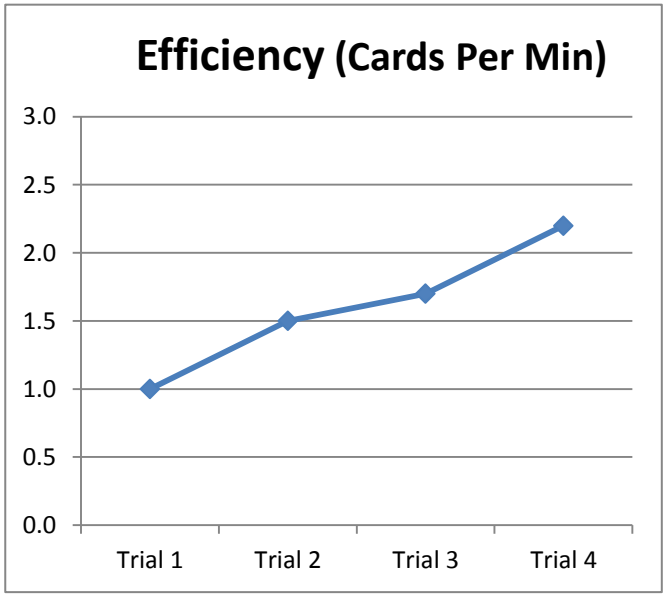
Introduction (5 minutes) Both teachers welcome the students to class and tells them they are going to be industrial engineers today. The math teacher explains that there are many kinds of engineers. For instance, civil engineers design roads and bridges, mechanical engineers design things with moving parts like machines, and computer engineers design computers. Industrial engineers, on the other hand, do not design products but figure out how to build them correctly and efficiently. In other words, a mechanical engineer might come up with the design for a new car, and then an industrial engineer will figure out how to produce 10,000 of those cars in a factory.

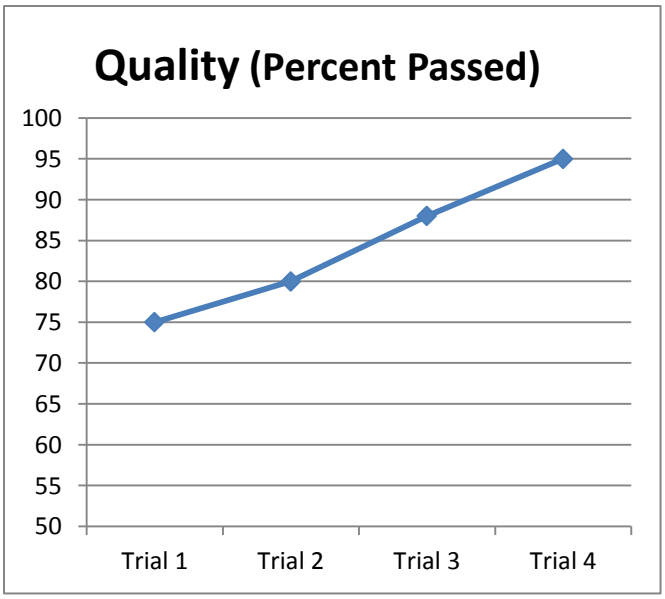
Demonstration (5 minutes) The art teacher explains that the product we will be building today is a greeting card. She shows the students a card she has already designed and then "builds" a new card, describing each step as she goes. As the art teacher is demonstrating the steps, the math teacher should bring the pre-prepared sign for each step into view.

Trial One (10 minutes) The students are then instructed that they will have 10 minutes to make as many cards as possible, each working individually. The math teacher, taking on the role of supervisor, sets a timer for 10 minutes and tells the students to START. At that point, each student may gather materials from the warehouse and begin constructing cards. Each time a card is completed, the student must hand it to the art teacher, who takes the role of quality control and sorts the cards into the pass and fail bins. After 10 minutes, the math teacher calls "STOP" and all production must cease.

Discussion One (5 minutes) The art teacher counts how many cards are in each bin and writes the results on the whiteboard. The math teacher leads a discussion in which the concepts of productivity, efficiency, and quality are introduced. She draws the three charts on the whiteboard (see figure), entering the data from Trial One. The **productivity** is the total number of cards is the pass bin. The **efficiency** is the productivity divided by 10 (since it was a 10 minute trial). The **quality** is the total number of cards passed divided by the total number of cards made, expressed as a percent.







Line Balancing (10-25 minutes) Students are then asked if they have any ideas as to how they could work more efficiently. If the students do not come up with the idea themselves, the teacher should suggest that they work as an **assembly line**. She will direct their attention to the small signs with each task and provide them with the large signs for the **workstations**. If time permits, students should work together using stopwatches to determine how much time it takes to complete each individual task. Using this data (or their best guess, if the timing step was skipped) the students should decide which tasks should

be done at which stations, and affix the correct steps to each workstation sign. The teacher will tell the students that distributing the tasks so that the total time for each workstation is approximately equal is called **line balancing**. They should also organize themselves as the workers at the various stations and move the materials from the central warehouse to the point where they will be needed in the assembly line. They may also place their partially completed cards in the correct workstations to be finished by the assembly line.

Trial Two (10 Minutes) When the students are ready, the math teacher says "START" and gives the students 10 minutes to produce as many cards as possible working as an assembly line. Each card should be inspected by quality control and placed into either the pass or fail bin.

Discussion Two (15 Minutes) At the end of Trial Two, the art teacher counts the cards in the pass and fail bins, and the three charts are updated accordingly. The math teacher leads a discussion where the students brainstorm ways in which their efficiency could be improved even more. The teacher should use this discussion to introduce the term **bottleneck** as the workstation that takes the longest time. The students should identify which workstation is the bottleneck, and decide if one of its tasks should be moved to a different workstation or if more workers should be assigned to the bottleneck workstation. They should also identify the workstation with the most **idle time**, and make appropriate changes. Finally, students should be invited to create a new workstation, the repair shop, which fixes cards in the fail bin and resubmits them to quality control.

Trial Three (10 minutes) When the students have completed their improvements to the assembly line, the math teacher says "START" and gives the students 10 minutes to once again produce as many cards as possible. At the end of the 10 minutes, the cards in the pass bin are counted and the productivity, efficiency, and quality charts are updated. If time permits, the students may be given the opportunity to make more improvements and complete a Trial Four.

Closing (15 minutes) Students should already be organized into their groups according to their workstation. One of the teachers leads a short discussion where the students are given a chance to discuss what they learned in this activity. The teacher also asks them to think of examples of products that are probably produced on an assembly line. Finally, student groups work together to complete the matching exercise.

Follow Up: At a later time, the students may vote on what to do with all the cards they have produced. For instance, they may each take some home for personal use, they may give the cards to school staff on Teacher Appreciation Day, or they can sell the cards as a fundraiser.

Assessments: Since this is a true authentic activity, the students will be assessing their own progress toward answering the essential question in the form of the productivity, efficiency, and quality graphs. Student understanding of the vocabulary related to industrial engineering can be informally assessed by the teachers during the discussions and when the groups complete the matching exercise (see attachment). Furthermore, the understanding of the vocabulary and concepts from this lesson can be

formally assessed with the quiz (see attachment) or by incorporating some of the questions from the quiz into the next unit test.

Adaptations for older students: This lesson is designed for the fifth grade, but it could certainly appeal to older students as well. Older students can produce more complex cards and will need less guidance from the teacher to complete the activities. For instance, instead of breaking the process down into several smaller tasks, the teacher should allow the students to do that on their own. Furthermore, the quality control standards can be higher for older students. High school students may benefit from watching the video on Line Balancing found at http://www.youtube.com/watch?v=XRIJaUa-_qM before designing their assembly line.

Reflection: I was able to use this lesson with my troop of junior Girl Scouts, all of whom are in the fourth grade. At the meeting when we did this activity, we had 11 girls in attendance and just over an hour to complete the activity. I acted as "supervisor" and my two co-leaders were the "quality control." We did have some girls with special needs, including ADHD and Asperger's, but they were able to complete the activity without modifications.

We started with a discussion about different types of engineers. All of the girls had heard of engineers; one had a dad who was a mechanical engineer, and another had a dad who was a chemical engineer. However, none of them had ever heard of an industrial engineer (except my own daughter, but even she had no idea what industrial engineers did.)

Trial One was complete chaos, just like it was supposed to be. I had all the materials in the "warehouse" and they were rushing to get their supplies. There was only one large hole punch available, and every girl had to take a turn using it. After 10 minutes, only two cards had been submitted to quality control, and only one of them passed. In the discussion after Trial One, the girls quickly came up with the idea to create an assembly line. Because we were pressed for time I assigned the tasks to each workstation, but I am sure the girls would have preferred to have done that step themselves. They did a very good job of organizing the materials so that each workstation had what it needed. The single hole punch was no longer a problem!

Trial Two went much better; the girls were able to make 11 cards, 8 of which passed quality control. Workstation 2 was a definite bottleneck, and Workstation 3 had a lot of idle time as a result. The girls grasped these concepts easily and shuffled workers around accordingly.

In Trial Three the girls made 16 cards, 14 of which passed quality control. When we calculated the efficiency and they realized they were making more than a card per minute, they were very excited! I was very pleased that the productivity, efficiency, and quality all increased with each trial. In the discussion afterward, I asked the girls what an industrial engineer did, and several hands when up. The girl I called on enthusiastically replied "they increase the efficiency of a process!" We did not have time for the closing worksheet or for a Trial Four, but the girls did run the assembly line for several more minutes because they wanted to use up the materials and because they were having fun. It also gave two other girls a chance to work in the repair shop, which was the most popular workstation.

If I have the opportunity to use this activity again, I hope to have the full 90 minutes so the girls can take more time to develop the assembly line themselves. I would also designate one student as "clean-up" since there was a lot of work for me after the girls went home. If the troop or class is larger, I will also designate a student as "materials manager" with the job of making sure that the workstations never run out of materials. I may also select a "packaging engineer" to put sets of 5 cards and envelopes into bags, since we intend to sell our cards in sets of 5. If this activity is used with more than 20 students, two parallel assembly lines may work better than one. Overall, the girls in my troop had a lot of fun and definitely learned about industrial engineering.

Inspirations:

Line Balancing Video: http://www.youtube.com/watch?v=XRIJaUa-_qM

Card Making Assembly Line: http://www.youtube.com/watch?v=udvLLn0Iml0

The Free Dictionary by Farlex: http://encyclopedia2.thefreedictionary.com/

AAUW Contest: http://www.aauw.org/article/teachers-enter-our-battle-of-the-plans/

Greeting Card Assembly Line

Matching Activity

Directions: Match each industrial engineering term with its definition.

1.) Industrial Engineer

2.) Productivity

3.) Efficiency

4.) Quality

5.) Quality Control

6.) Assembly Line

7.) Task

8.) Workstation

9.) Line Balancing

10.) Bottleneck

11.) Idle Time

12.) Warehouse

A. a location where specific tasks are designated to be carried out

B. the process that or person who ensures the quality of the product

C. A measure of total output

D. a place to store materials

E. an arrangement of machines, workers, and materials organized in such a way that at each stage an additional part of the manufacturing process is carried out

F. A measure of output per unit of time

G. the workstation that take the longest to complete its tasks

H. an individual step in a more complex process

I. a type of engineer who is concerned with efficient production

J. the degree of excellence or acceptability

K. a period of time in which workers are not productive

L. the process of assigning tasks to workstations so that the total time to complete the tasks at each workstation is approximately equal

Greeting Card Assembly Line

Matching Activity Answer Key

Directions: Match each industrial engineering term with its definition.

1.) Industrial Engineer **I**

2.) Productivity **C**

3.) Efficiency **F**

4.) Quality **J**

5.) Quality Control **B**

6.) Assembly Line **E**

7.) Task **H**

8.) Workstation **A**

9.) Line Balancing **L**

10.) Bottleneck **G**

11.) Idle Time **K**

12.) Warehouse **D**

A. a location where specific tasks are designated to be carried out

B. the process that or person who ensures the quality of the product

C. A measure of total output

D. a place to store materials

E. an arrangement of machines, workers, and materials organized in such a way that at each stage an additional part of the manufacturing process is carried out

F. A measure of output per unit of time

G. the workstation that take the longest to complete its tasks

H. an individual step in a more complex process

I. a type of engineer who is concerned with efficient production

J. the degree of excellence or acceptability

K. a period of time in which workers are not productive

L. the process of assigning tasks to workstations so that the total time to complete the tasks at each workstation is approximately equal

Name: _____

Date: _____

Greeting Card Assembly Line

Quiz

True or False Questions

Directions: Circle **True** or **False** for each statement.

1.) Industrial engineers design assembly lines.
TRUE FALSE

2.) Building products quickly is more important than making sure they have acceptable quality.
TRUE FALSE

3.) A warehouse is a location for storing materials.
TRUE FALSE

4.) A bottleneck is a workstation with a lot of idle time.
TRUE FALSE

5.) Industrial engineers try to *reduce* productivity and efficiency.
TRUE FALSE

Multiple Choice Questions

Directions: Circle the choice that best answers the question or completes the statement

6.) Which of the following is an industrial engineer most likely to design?
   a. A car
   b. A computer
   c. A bridge
   d. A process for building any of the above

7.) Which of the following is the best method for building a lot of the same product over and over again?
    a. Assembly Line
    b. Trial and Error
    c. Quality Control
    d. Idle Time

8.) What is one way to improve the efficiency of an assembly line?
    a. Perform each task more quickly
    b. Store materials in the location where they will be used
    c. Have fewer rejections by quality control
    d. All of the above

9.) An assembly line is balanced when
    a. The materials in each workstation weigh the same amount
    b. The total time to complete the tasks is about the same in each workstation
    c. Every workstation has the same number of workers
    d. Every workstation has the same number of tasks

10.) A bottleneck is
    a. The workstation that takes the most amount of time
    b. The workstation that takes the least amount of time
    c. The workstation that uses the most materials
    d. The workstation that uses the least materials

Short Answer Questions

Directions: Answer the following questions with full sentences or by creating graphs.

11.) Sunnyside Card Co is a factory that produces greeting cards that are sold in stores across the country. Last week, Sunnyside was able to produce 10,254 cards on Monday, 12,380 cards on Tuesday, 11,587 cards on Wednesday, 6,457 cards on Thursday, and 12,007 cards on Friday. Draw a graph that shows Sunnyside's productivity for last week.

12.) Assuming that Sunnyside's factory is in operation for 8 hours each day, create a graph that shows the efficiency in cards per hour for each day last week.

13.) One of Sunnyside's printing machines broke down last week. On what day do you think this most likely happened? Why?

14.) Imagine you are the industrial engineer at Sunnyside Card Co. Give at least three ideas you might have to improve Sunnyside's efficiency.

Name: _____

Date: _____

Greeting Card Assembly Line

Quiz Answer Key

True or False Questions

Directions: Circle **True** or **False** for each statement.

1.) Industrial engineers design assembly lines.
(TRUE) FALSE

2.) Building products quickly is more important than making sure they have acceptable quality.
TRUE (FALSE)

3.) A warehouse is a location for storing materials.
(TRUE) FALSE

4.) A bottleneck is a workstation with a lot of idle time.
TRUE (FALSE)

5.) Industrial engineers try to *reduce* productivity and efficiency.
TRUE (FALSE)

Multiple Choice Questions

Directions: Circle the choice that best answers the question or completes the statement

6.) Which of the following is an industrial engineer most likely to design?
a. A car
b. A computer
c. A bridge
(d.) A process for building any of the above

7.) Which of the following is the best method for building a lot of the same product over and over again?

a. Assembly Line
b. Trial and Error
c. Quality Control
d. Idle Time

8.) What is one way to improve the efficiency of an assembly line?

a. Perform each task more quickly
b. Store materials in the location where they will be used
c. Have fewer rejections by quality control
d. All of the above

9.) An assembly line is balanced when

a. The materials in each workstation weigh the same amount
b. The total time to complete the tasks is about the same in each workstation
c. Every workstation has the same number of workers
d. Every workstation has the same number of tasks

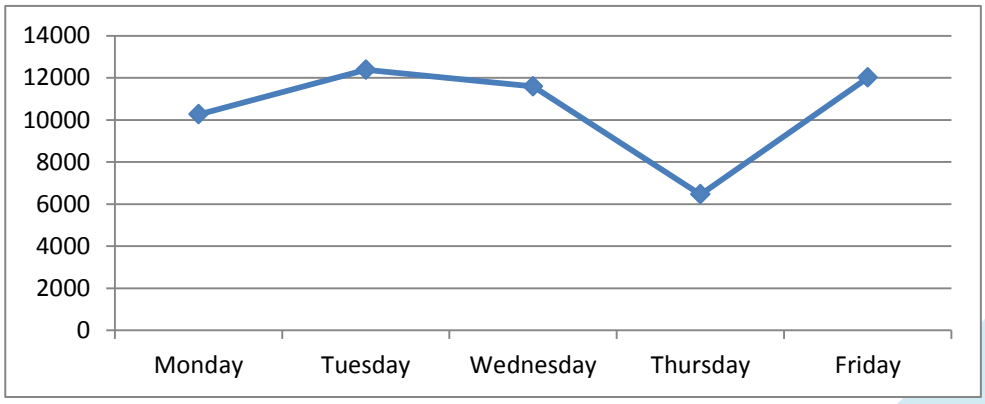
10.) A bottleneck is

a. The workstation that takes the most amount of time
b. The workstation that takes the least amount of time
c. The workstation that uses the most materials
d. The workstation that uses the least materials

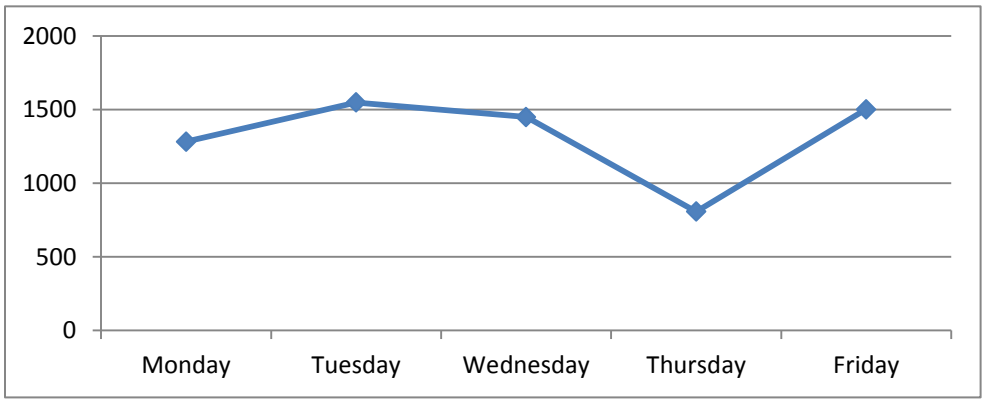
Short Answer Questions

Directions: Answer the following questions with full sentences or by creating graphs.

11.) Sunnyside Card Co is a factory that produces greeting cards that are sold in stores across the country. Last week, Sunnyside was able to produce 10,254 cards on Monday, 12,380 cards on Tuesday, 11,587 cards on Wednesday, 6,457 cards on Thursday, and 12,007 cards on Friday. Draw a graph that shows Sunnyside's productivity for last week.



12.) Assuming that Sunnyside's factory is in operation for 8 hours each day, create a graph that shows the efficiency in cards per hour for each day last week.



13.) One of Sunnyside's printing machines broke down last week. On what day do you think this most likely happened? Why?

This probably happened on Thursday, because the productivity and efficiency were lowest on Thursday.

14.) Imagine you are the industrial engineer at Sunnyside Card Co. Give at least three ideas you might have to improve Sunnyside's efficiency.

Possible answers include, but are not limited to:

- Storing materials where they are needed
- Finding the exact time to complete each step of the process
- Balancing the assembly line so that each workstation takes about the same amount of time
- Hiring more workers and/or purchasing more machines
- Avoiding bottlenecks and/or minimizing the idle time at each workstation
- Ensuring that most cards are accepted by quality control
- Repairing cards that do not pass quality control

Winner of the 2013 AAUW
Battle of the Plans: Engineer a Lesson contest

Learn more at www.aauw.org.